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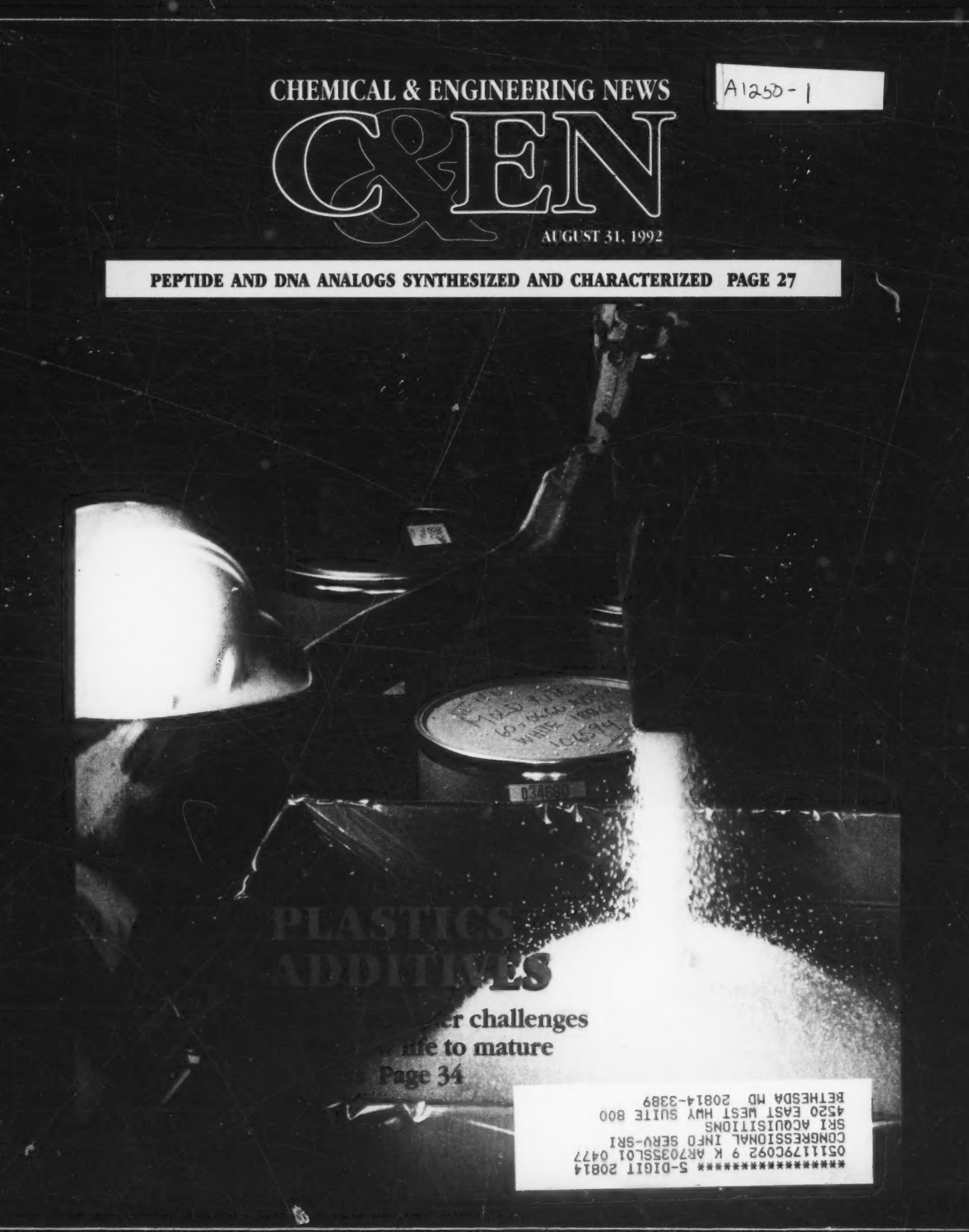
CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 31, 1992

PEPTIDE AND DNA ANALOGS SYNTHESIZED AND CHARACTERIZED **PAGE 27**



PLASTICS ADDITIVES

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Page 34

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 31, 1992

NEWS OF THE WEEK

■ Dutch scientists prepare organic polymers that are more metal-like in electrical properties than any previously known. Page 8

■ Mycogen has settled dispute with Novo Nordisk over patent rights on biopesticide. Page 9

■ Special poster session at ACS national meeting in Washington spotlighted Russian materials science research. Page 9

■ Hurricane Andrew generally left chemical plants unscathed as it roared through Louisiana last week. Page 9

■ ACS decided during the national meeting to expand activities in such areas as public outreach, education, and professional development. Page 10

■ Researchers at Searle and Du Pont have developed a new class of drugs that attack inflammatory diseases. Page 11

■ In-situ method for preparing thin films of thallium superconductors has been found by Du Pont scientists. Page 11

■ Dollar's dive to record lows against the German mark promises to boost U.S. chemical exports to Europe. Page 12

COVER: Worker fills container with final compounded polymer. Photo courtesy of Ciba-Geigy

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BUSINESS

Revenues were up for biotech companies in the first half, but only five firms had profits, largely because of increased expenses from mergers, R&D, and marketing. Page 15

GOVERNMENT

The Senate tacked on new tax provisions to the energy policy bill, substantially boosting its chances for enactment before the end of the 102nd Congress. Page 24

SCIENCE/TECHNOLOGY

Peptidelike compounds and homologous DNA, which differs from natural DNA only in the size of its sugar ring, have been synthesized and characterized. Page 27

Nanometer-scale galvanic cell, much smaller than a red blood cell, could provide a route to the study of electrochemical processes at the atomic level. Page 29

Three-dimensional molecular modeling software will be offered for Digital's Alpha computers under a joint marketing pact between Digital and Molecular Simulations. Page 30

EDUCATION

Planned cuts in San Diego State University faculty that would have hit the university's chemistry department hard have been put off at least until 1993. Page 33

PRODUCT REPORT

Forecast growth for plastics additives industry has producers gearing up to meet demands of a global market, needs of new polymer systems and end-use customers, and requirements of new and pending environmental rules. Page 34

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LETTERS

CHEMICAL SAFETY

Borane-methyl sulfide complex spill reported

We wish to report a recent incident involving a spill of borane-methyl sulfide complex that resulted in injuries to three employees, two serious enough to warrant hospitalization for medical observation.

The accident occurred as an 800-mL Sure-Seal bottle of neat borane-methyl sulfide complex (Aldrich catalog no. 179825) was unpacked for storage. The bottle had been removed from its protective packaging and was being carried to the refrigerator for storage when it burst spontaneously, splashing one person over much of his body with the reagent. With the assistance of another person, he was placed under a safety shower immediately, and contaminated clothing and shoes were removed. The water from the shower began to react with the spilled borane-methyl sulfide, worsening the already deteriorating laboratory atmosphere, and the laboratory was evacuated as soon as the employee could be moved. Both employees involved at the shower suffered from intense irritation to their eyes and respiratory passages, and were treated with oxygen and eye irrigation.

Our investigation of this accident suggested that it was probably the result of a potentially defective glass container of borane-methyl sulfide. The bottle had been inspected immediately prior to the accident and was not warm to the touch, nor did it or the packaging show any signs of damage. However, shards of the broken bottle recovered after the accident revealed that the bottle appeared to have fractured from within at a particularly thin point (1.5 mm thick) in the side wall of the bottle. We believe that the breakage was probably caused by an accumulation of hydrogen within the bottle.

Upon subsequent discussion of this incident with Aldrich, we learned that all borane complexes, with the possible exception of borane-amine complexes, decompose in a time- and temperature-dependent manner to higher borone hydrides and hydrogen. Thus, any borane

Research fraud

The federal prosecutors' decision not to press criminal charges against Thereza Imanishi-Kari, as reported in Pamela Zurer's article (C&EN, July 20, page 5), is probably a wise one. Unless research fraud is of a kind easily discernible, as for example plagiarism or fabrication of research data based on fictitious experiments, it is difficult, if not impossible, to prove that fraud has occurred, whether or not the jury selected in a criminal trial is composed of knowledgeable scientists. Nonrepeatability of experimental results is, by itself, not proof of research fraud, since other explanations are possible without impugning the integrity of the authors.

On the other hand, even if this highly visible case had been prosecuted, whether successfully or unsuccessfully, the fact remains that one may commit research fraud without its being detected, thereby increasing one's productivity, and, in this way, advancing one's career. It is also true that Margot O'Toole's career was very nearly destroyed as a result of her questioning the authenticity of research data in the famous 1986 *Cell* paper [**45**, 247 (1986)]. Is the withdrawal of the retraction of that paper by its senior author, Nobel Laureate David Baltimore, a reaffirmation of his initial evaluation of O'Toole as a "disgruntled" junior scientist? Further, it would appear that this long-drawn-out case has come full circle, which leads to the question: What does the Dingell committee do next?

What it has done is to partly expose academia's dark side and the ineptness of the National Institutes of Health in bringing its lengthy fraud investigation to a successful conclusion. Possibly the most important contribution this committee

Correction

- Aug. 24, page 28: The crystal structure of HIV-1 reverse transcriptase, not the HIV-1 Tat protein, has been solved to 3.5-Å resolution; see *Science*, **256**, 1783 (1992).

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Biotech Firms' Revenues Up But Earnings Weak in First Half

■ ***Higher expenses from mergers, acquisitions, R&D, and marketing take big bite out of revenues, drive down earnings***

Biotechnology companies had very mixed results in the first half of 1992. Although revenues increased significantly for many companies, relative to the same period last year, earnings continued to be bleak. This situation may change in the second half of the year as some companies finally rid themselves of merger- and acquisition-related expenses. But at the same time, increasing R&D spending and costs associated with setting up marketing and sales efforts will continue to eat away at revenues.

The big exception is Amgen, which has clearly established itself as a biopharmaceutical force with two major products—the blood cell stimulants erythropoietin (EPO) and granulocyte colony-stimulating factor. Amgen's revenues grew 64% over first-half 1991 to $481 million. Although Amgen's 1991 annual sales already placed it among the Fortune 500, the question for 1992 will be whether it breaks the $1 billion mark.

First-half 1992 earnings of $135 million following a loss of $11.5 million in last year's first half resulted in a profit margin of 28% for Amgen, allowing it to increase R&D spending 41% to about $81 million. If not for a special charge taken in the first half of 1991, earnings would have increased 75%. The special charge, for $129 million and related to an arbitration settlement with EPO licensee Johnson & Johnson, contributed to Amgen's first-half 1991 loss.

The sizable increases in revenues registered by many other companies can be deceptive since they measure gains from very small revenue bases or those resulting primarily from R&D contract revenues or interest income rather than from product sales. Revenues of companies with sales or royalties from major products, such as Biogen, Centocor, Chiron, Genentech, Genzyme, and Immunex, increased an average of 60%. However, excluding Genentech and Amgen, they increased 82%.

Genentech's revenues rose only 1%, as product sales dropped 4% in the first half compared with the year-earlier period. Much of this was due to a 12% drop in sales of its antithrombolytic, tissue plasminogen activator, in the second quarter, but was counterbalanced by an 8% rise in human growth hormone sales. With R&D expenses up 37%, Genentech's earnings for the first half dropped 77% to $6.9 million.

Similarly, Immunex's sales were hurt by its now resolved marketing problems with Behringwerke and Hoechst

Only five biotech firms had profits in first-half 1992

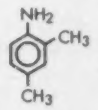
$ Thousands	Revenues[a]	Earnings	% change from first-half 1991 Revenues	% change from first-half 1991 Earnings	Profit margin[b] 1992[c]	Profit margin[b] 1991[c]
Affymax	$ 6,004	$ –4,633	561%	nm	def	def
Agouron Pharmaceuticals	4,274	–4,545	82	nm	def	def
Alkermes	3,350	–4,085	2580	nm	def	def
Amgen	481,459	134,888	64	nm	28.0%	def
Biogen	40,027	1,479	43	–71%	3.7	18.4%
BioTechnology General	3,148	–4,772	45	nm	def	def
Cambridge Biotech	20,771	1,410	63	nm	6.8	def
Centocor	42,188	–85,490	72	nm	def	def
Cephalon	4,000	–2,388	–21	nm	def	30.8
Chiron	125,503	–45,086	96	nm	def	15.1
Cor Therapeutics	881	–4,285	–47	nm	def	def
Cytogen	8,715	–5,466	290	nm	def	def
Genentech	264,964	6,936	1	–77	2.6	11.8
Genetic Therapy	832	–3,389	576	nm	def	def
Genetics Institute	33,858	–37,461	29	nm	def	def
Genzyme	94,695	–48,709	116	nm	def	15.9
Gilead Sciences	1,140	–1,758	128	nm	def	def
Icos	1,328	–3,127	225	nm	def	def
Immune Response	5,499	–754	57	nm	def	def
Immunex	31,764	–6,241	29	nm	def	def
Isis Pharmaceuticals	4,796	–9,269	37	nm	def	def
Liposome	5,390	–3,083	45	nm	def	def
MedImmune	7,914	266	327	–82	3.4	18.9
Oncogene Science	5,974	–2,246	51	nm	def	def
Regeneron	6,726	–6,976	27	nm	def	def
Ribi ImmunoChem	1,009	–1,759	61	nm	def	def
Scios	4,460	–5,964	–2	nm	def	def
Synergen	23,494	–3,404	182	nm	def	def
SyStemix	207	–15,889	–79	nm	def	def
Xoma	3,810	–19,202	–62	nm	def	def

a Includes product sales, contract research, royalty, and interest revenues for calendar year. b After tax income as percentage of revenues. c First half. **def** = deficit. **nm** = not meaningful.

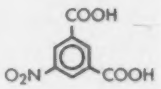
Organic Intermediates

for pharmaceuticals, agrochemicals, dyestuffs, flavors, fragrances, photochemicals, etc.

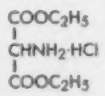
2,4-Xylidine
and other isomers



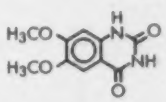
5-Nitroisophthalic acid
and derivatives



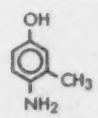
Aminomalonic acid diethyl ester · HCl
and Acetylaminomalonic acid diethyl ester



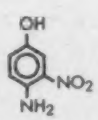
6,7-Dimethoxy-quinazoline-2,4-dione



4-Amino-m-cresol
and other isomers



4-Amino-3-nitrophenol



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Agricultural biotech firms not yet breaking even

Companies developing genetically engineered plants, pesticides, and foods have yet to turn the corner financially. A few are getting close—such as Mycogen, Ecogen, and Calgene—but have been spending money to acquire businesses and products, and to prepare for marketing. Expenses also have remained high because it has taken several years for companies to develop the science behind new products. Revenues are up, however, for five of the six most prominent agricultural biotechnology firms and losses remain modest in comparison to high-spending biopharmaceutical companies.

$ Thousands	Revenues[a]	Earnings	% change from first-half 1991 Revenues	% change from first-half 1991 Earnings	Profit margin[b] 1992[c]	Profit margin[b] 1991[c]
Biosys	$ 1,854	$–2287	198%	nm	def	def
Calgene[d]	10,209	–2387	–19	nm	def	2.2%
Crop Genetics	1,407	–2949	37	nm	def	def
DNA Plant Technology	5,379	–7800	3	nm	def	def
Ecogen	3,847	–5788	11	nm	def	def
Mycogen	19,752	–1439	175	nm	def	def

a Includes product sales, contract research, royalty, and interest revenues for calendar year. b After-tax income as percentage of revenues. c First half. d Only first quarter available. **def** = deficit. **nm** = not meaningful.

Roussel, licensees for granulocyte macrophage-colony stimulating factor (C&EN, July 27, page 21). Sales still rose 74% to $22 million for the first half of 1992. Increased R&D spending, as the company expanded its clinical trials, led to a net loss of $6.2 million.

Other than Amgen and Genentech, only three of the 30 biotech firms surveyed—Biogen, Cambridge Biotech, and Medimmune—showed a profit for the first half of 1992. Biogen's revenues grew substantially, primarily because of royalties on major biopharmaceuticals such as α-interferon and hepatitis B vaccine. But in putting its first proprietary drug product, the antithrombolytic Hirulog, into advanced clinical trials, R&D spending rose 37% to $28.3 million and earnings dropped 71% to $1.5 million.

Genzyme and Chiron, which recorded profits in the first half of 1991, reported losses for the same period in 1992. First-half revenues for Genzyme increased 116% to $94.7 million, largely owing to sales of Ceredase, its product for treating Gaucher's disease. But nonrecurring charges of $51 million for acquiring in-process R&D and $17 million to write off its option on Neozyme II led to a net loss of $48.7 million.

Chiron was in a similar situation with a $40 million charge related to its acquisition with Ciba-Geigy of the Italian vaccine producer, Sclavo. This contributed to a net loss of $45 million, despite revenues up 96% to $126 million for the first half. R&D spending doubled to $60 million, in part because of $17 million for research acquired with Cetus in December 1991. Cetus' oncology business, which now includes the May 1992 U.S. launch of interleukin-2, contributed $18.8 million in sales.

Along with Genzyme and Chiron, several other prominent companies—Centocor, Genetics Institute, SyStemix, and Xoma—reported huge losses. With revenues up 72% to $42.2 million for the first half, Centocor cut its loss to $85.5 million after reporting a $117 million loss for the year-earlier period. Centocor's antisepsis drug, Centoxin, did contribute $9.6 million in European sales in the first half of 1992. And Centocor's new alliance with major pharmaceutical partner Eli Lilly is expected to bring in at least $100 million.

As for Genetics Institute and SyStemix, both had special charges relating to mergers. Xoma's loss, however, was due primarily to a drop in collaborative R&D funding and a $3.3 million legal settlement. SyStemix took a $12.2 million special charge relating to Sandoz's acquisition of a 60% interest in early 1992. For the first half of 1992, SyStemix reported a net loss of $15.9 million. Similarly, Genetics Institute reported a $37.5 million loss after taking a $30 million charge associated with American Home Products' acquiring a 60% stake in January.

Ann Thayer

PLASTICS ADDITIVES

Susan J. Ainsworth, C&EN Houston

Plastics are everywhere—in automobile parts, in components for houses and buildings, and in packaging for everything from food to electronic parts. Plastics would not be able to perform such diverse functions without the assistance of a very broad range of plastics additives. Polyvinyl chloride (PVC), polyolefins, polystyrene, and polyester resins rely most heavily on additives. Without them, some plastics would degrade during processing and, over time, the polymers would lose impact strength, discolor, and become statically charged, to list just a few problems. Additives not only overcome these and other limitations but also can impart improved performance properties to the final product.

Because plastics and additives markets are so interdependent, their growth rates are virtually one and the same: The plastics business has been buffeted by recession, and the additives business has been hit just as hard. But things are looking up, companies say. The plastics additives industry should enjoy moderate growth during the next five years as plastics consumption recovers from the recession.

U.S. demand for plastics additives is projected to increase 4.1% per year to 12.5 billion lb in 1996, if manufacturers of these additives can lower resin costs and improve physical characteristics and processibility of plastics, according to the May 1992 study, "Plastics Additives in the 1990s," by Freedonia Group, a consulting firm based in Cleveland.

For the most part, additive producers agree. Many expect to see volume growth of between 2 and 6% during the next five years, depending on what additives are taken into account. For example, according to Avron Magram, vice president and general manager of the plastics additives and specialty lubricants group at Hüls America, "If you include a no-growth business such as commodity plasticizers, growth rates should fall to around 1.5 to 2%. If that business is not considered, my outlook is much more bullish and I put growth rates at 5 to 6% per year."

Although plastics and plastics additives businesses are fairly mature, the additives business is far from stagnant. On the contrary, additive producers are perhaps busier than ever trying to meet the changing needs of their customers.

For example, their most prized customers—the resin producers—are becoming more multinational. In response, many U.S.-based additive suppliers are globalizing their distribution networks, setting up more manufacturing and technical centers outside the U.S., and reshuffling internal divisions to strengthen the geographic scope of their businesses.

Additives producers are also hard at work tackling a number of their customers' technical challenges, hoping to carve out new niches and more profits. New additive technologies are needed to address the problems that accompany new polymer systems and to meet increasing performance demands from end-use customers, such as the automotive industry.

Another challenge facing producers: developing alternative additives to meet customer requirements that are changing as a result of proposed legislation or public demands for environmentally friendly and recyclable plastic products. "We believe that environmental issues provide opportunities for us to develop new technology and to differentiate ourselves from competitors," says Jean Schaeflé, president of Ciba-Geigy's U.S. pigments division. "We have to consistently produce high-quality pigments that provide our customers and [our customers'] customers with the qualities they want, but our pigments also have to be environmentally acceptable. [They have to be] acceptable in the workplace and in production processes, acceptable from a waste- and resource-management standpoint, and acceptable for consumers."

Although regulations present opportunities for additive producers who can develop alternative product technologies, regulations also have negative effects on businesses—compliance is usually labor intensive and adds costs for which there is no return on investment. Those companies that do not have the capital or the clout to face these challenges will be added to the ever growing list of casualties in the continually consolidating additives business, says Steven Hopper, marketing manager for PVC and target markets at C. P. Hall, based in Chicago.

Additive suppliers say they have to provide more research and development support to the plastics industry. Formulating with plastics additives has always been a tricky business. Incorpo-

Ciba-Geigy photo

Worker scoops out granular pigments that will be used in the production of polymers

rating additives in a polymer requires a fine balance between the properties of the polymer and the additive. Formulating a plastic for enhanced ultraviolet light resistance, for example, can have an impact on the polymer's color stability and retention of its functional characteristics. Similarly, incorporating antioxidants in a polymer melt can inhibit the cross-linking ability of a peroxide catalyst. So formulators need to choose carefully additives that not only possess a specific functionality but that also minimize the effect on other additives and the formulated plastic. Consequently, both the additive supplier and the resin formulator, compounder, or manufacturer have had to devote considerable research and development time to achieve the best balance of properties in the final product. But now, additive suppliers say they are experiencing a greater proportion of the pressure.

With the U.S. plastics business recovering from the effects of the recession, few resin manufacturers want to spend the capital required to fully research new additive offerings. In many cases, it's easier and less costly for them to keep using what works now. So additive producers that want to sell their products must do the testing required and provide proof statements that show their product has better cost or performance benefits than resin manufacturers' old standbys.

"Additive producers must bring more technology to the table to win business," says Hopper. "Proof statements have become very sophisticated." The statements must be broader and show—in detail—what parameters the additives have been tested for and how they compare with other products on the market. "There's more pressure on the additive suppliers to provide vast amounts of data on their additives," adds Hopper. "Simply saying your product is new and improved does not get you in the door anymore."

At the same time, additive producers face a major technical challenge of providing quality and consistency—a concept that has permeated the industry. "Even if a UV absorber makes up only one tenth of one percent of a plastic formation, that additive must be exactly the same day after day. We have to set a standard and meet it each and every time. That's a big technical challenge considering that one additive may have a positive effect on a polymer as well as an offsetting negative effect at the same time," says Hüls' Magram.

Recognizing the business potential behind new additives technology, several additive producers are aggressively involved in developing compatibilizing agents for blends or alloys. "It's a small area now, but one in which we see innovative growth opportunities," says Robert Terranova, vice president of inorganic chemicals at Lonza. Thomas E. Galvanek, a vice president at the Houston-based international plastics and chemicals consulting firm Phillip Townsend Associates, agrees that the market for compatibilizing agents is one of the most dynamic and rapidly growing specialty chemical areas. On the basis of data in the firm's recently published report on this topic, overall

How do additives work?

Plastics additives include an array of products that can improve the performance of plastics or overcome processing problems. The functional properties of some of the major classes of plastics additives are discussed below. But the plastics industry also relies on several other classes of additives such as antiblocking and antislip agents, biocides, peroxide and polyurethane catalysts, colorants, coupling agents, defoamers, fillers and reinforcements, plasticizers, thickeners, and wetting agents.

Antioxidants retard the oxidative degradation of a plastic. Degradation is initiated when free radicals—highly reactive species with an unpaired electron—are created in the polymer by heat, ultraviolet radiation, mechanical shear, or metallic impurities. Without the protection of antioxidants, loss of molecular weight, brittleness, discoloration, cross-linking, and deterioration of other polymer properties would occur.

When a free radical is formed, a chain reaction begins that initiates polymeric oxidation. Subsequent reaction of the radical with an oxygen molecule yields a peroxy radical, which then reacts with an available hydrogen atom to form an unstable hydroperoxide and another free radical. In the absence of an antioxidant, these reactions become self-propagating and lead to polymer degradation.

There are two basic types of antioxidants—primary and secondary. Primary antioxidants intercept and stabilize free radicals by donating active hydrogen atoms. Hindered phenols and aromatic amines represent the two main types of primary antioxidants. Secondary antioxidants prevent formation of additional free radicals by decomposing the unstable hydroperoxides into a stable product. Phosphites and thioesters are secondary antioxidants that function by decomposing hydroperoxides, thus preventing free-radical formation. Phosphites are also frequently used as costabilizers with polyvinyl chloride (PVC) heat stabilizers. Secondary antioxidants, or synergists, are often used along with primary antioxidants. They decrease the discoloration of the polymer, and may also regenerate the primary antioxidant.

Antistatic agents or antistats, when formulated in or coated on plastics, dissipate static electrical charges. Such charges build up on the surface of plastics because they are insulating materials and cannot independently dissipate a charge. Dissipating static electricity prevents problems such as sparking, dust attraction, or interference during processing.

There are two types of antistats—external and internal. External, or topical, antistats are applied to the surface of a polymer through techniques such as spraying, wiping, or dipping. These coatings often serve a cosmetic function by keeping dust from settling on plastic surfaces. Internal antistatic systems are compounded into the resin during processing. These agents have the ability to replenish the polymer's antistatic protection, often worn off during handling, through a process called blooming—the migration of the antistat to the polymer surface. The internal antistats, therefore, can offer long-term protection against static electrical charges.

Antistats are usually hygroscopic compounds, and thus absorb moisture from the surrounding air. It is this conductive layer of water on the polymer surface that disperses the charge. The two major types of specialty antistatic agents are quaternary ammonium compounds and amines, and their associated derivatives. Phosphate and fatty acid esters, polyhydric alcohol derivatives, sulfated waxes, ethoxylated and propoxylated aliphatics and aromatics, and other materials are also used.

Chemical blowing agents (CBAs) are used to make foamed plastics. Physical blowing agents are volatile liquids or compressed gases that, because of changes they undergo during processing of the plastic, give the plastic a cellular structure. Gases, such as nitrogen, carbon dioxide, and air, or low-boiling liquids, such as short-chain hydrocarbons, are dissolved in the resin and are volatilized by the release of pressure or the heat of processing. CBAs are solids that generate gases when decomposed by the heat of processing, generating a foamed product. Mainly solid hydrazine derivatives, CBAs are designed to decompose within well-defined temperature ranges that can be lowered by the addition of activating compounds. Some heat stabilizers, such as tribasic lead sulfate, dibasic lead phthalate, and dibasic lead phosphite, may act as activators that reduce the temperature needed to produce the gas.

Compatibilizers are agents that provide permanent miscibility or compatibility between otherwise immiscible or partially immiscible polymers, creating homogenous materials that do not separate into their component

sales of these products are projected to increase from $20 million in 1990 to more than $100 million in 1995.

Compatibilizing agents provide permanent miscibility or compatibility between otherwise immiscible or partially immiscible polymers, creating homogenous materials that do not separate into their component parts. Because the desired compatibilization can be achieved in many ways, a wide array of materials can function as compatibilizers. Several of the most prevalent types include maleic anhydride modified polymers, monomeric polymers, and silanes.

Compatibilizing agents have been used in polymer blending and alloying for the past decade. However, recently these materials have developed into a significant segment of the plastics additives industry. Compatibilizers are primarily used in the production of polymer blends and alloys produced from virgin resins. Polycarbonate is by far the most important base resin, accounting for about three quarters of all compatibilizer demand in 1990, says Phillip Townsend Associates. The only other significant base resin is nylon. The greatest area of potential for compatibilizers is in recycling of plastics. By 1995, says the consulting firm, recycling will account for more than half of the demand for compatibilizers.

Additive producers are also hard at work trying to improve products they already supply to end-use customers. For example, William Avrin, vice president and general manager of the polymer additives department at American Cyanamid, believes growth opportunities for plastics additives used in the automotive industry will spur producers to improve the performance and longevity of plastics used to make parts. "Automotive companies are now trying to build cars that last 10 years, so

parts. Compatibilizers function as solid polymeric surfactants, in that they promote miscibility by reducing interfacial tension. They typically concentrate at the phase boundaries, and regulate interphase adhesion.

These compatibilizing agents can be further classified as reactive and nonreactive. Reactive compatibilizers chemically react with polymer systems during compounding, and they are effective across generally broader ranges of systems than are nonreactive types. However, the degree of compatibilization they provide depends strongly upon compounding conditions. Nonreactive compatibilizers, which are often block or graft copolymers (but may not be polymers at all), interact physically, not chemically, with the polymer system during compounding. Generally, nonreactive compatibilizers can only be used with a fairly narrow range of matrices.

Flame retardants are chemical compounds that can be physically blended into a resin, or can react to become part of the polymer. They are used to treat a product so that its resistance to burning is improved or modified. Flame retardants are designed to interfere with combustion both physically and chemically but not to prevent the product from burning if sufficient heat and oxygen are present. Such interference can occur in the vapor phase, in the condensed phase, or in both.

Heat stabilizers are added to resins to prevent thermal degradation. Although such protection is usually essential in processes such as molding and extrusion, particularly for PVC resins, these additives also extend the useful life of finished products that are exposed to heat. Lubricants, UV stabilizers, and synergistic antioxidants, especially organophosphites, are frequently used in conjunction with heat stabilizers. The most typically used chemicals include lead compounds, organotin compounds, and mixed metal-salt blends based on such products as barium, cadmium, and zinc.

Impact modifiers are formulated into plastics to improve the resistance of the finished product to stress. These additives are usually elastomeric, although certain types of plastics may also be used. Major classes of impact modifiers are methacrylate-butadiene-styrene, methacrylate-acrylonitrile-butadiene-styrene, acrylonitrile-butadiene-styrene, chlorinated polyethylene, ethylene-vinyl acetate, and acrylic. Acrylic processing aids are materials added to improve the processing characteristics of PVC and are typically used with impact modifiers. They accelerate the melting process and improve the rheological and mechanical properties of the melt. Processing aids are usually copolymers of methyl methacrylate and other acrylates.

Lubricants are added to resins to improve the flow characteristics of the plastic during processing. They function by reducing melt viscosity or by reducing adhesion between the metallic surfaces of the processing equipment and the melted polymer. Polarity, melting point, and solubility in the resin are key considerations when a lubricant is selected. Lubricants that reduce molecular friction, thus lowering the polymer's melt viscosity and improving its flow, are referred to as internal lubricants. Substances that promote resin flow by reducing friction of the melt as it contacts the surfaces around it are considered external lubricants. In practice, however, all plastics lubricants exhibit internal and external effects. Major classes of lubricants include amides, esters, metallic stearates, waxes, and acids.

Ultraviolet stabilizers help plastics resist light degradation. UV radiation in the range of 290 to 400 nm is absorbed by polymers that contain chemical groups called chromophores. If the absorbed energy is not dissipated, bonds within the polymer are broken and a free-radical chain reaction is initiated, which causes discoloration, embrittlement, and eventual degradation of the polymer. Thus, most polymers designed for outdoor use need to be stabilized with additives that either absorb more UV light than the polymer itself or deactivate the harmful free radicals and hydroperoxides as they are formed.

Benzophenones and benzotriazoles are two widely used commercial products that do act as UV absorbers. Although hindered-amine light stabilizers and nickel-containing complexes are used as antioxidants, they are not effective screening agents for ultraviolet radiation. Instead they stabilize the resin via free-radical termination and excited-state quenching.

The ideal additive would absorb all UV radiation but no visible light. In practice, a compromise has to be made. If no color is desired in the product, some UV transparency must be tolerated, or, alternatively, yellow discoloration must be allowed to achieve maximum UV absorption.

they want a bumper that will last twice as long as it used to and that puts new demands on the polymers and additives that go into that bumper," he explains.

"Clearly, new automotive systems are raising demands for additives," adds Hall's Hopper. For example, growth in the use of driver-side air bags has created the need for a plastic cover that can deploy very quickly without tearing and work under a very broad range of temperatures. This is a performance-driven application that represents a fast-growing niche for certain plastics additives, he notes.

Another existing market for additives that is creating some new challenges and opportunities is the polyurethanes business. Companies like Hall are anxious to develop new additives that may help polyurethane producers in their quest to "selectively extract" market share from those markets in which PVC and rubber are now dominant, says Hopper. With this market focus in mind, Hall is supplying polyurethane producers with a proprietary line of Urethhall polyester polyols that unlike traditional products, are not based on adipic acid. These new polyols allow polyurethane producers to achieve new performance properties so that they can compete with softer materials like rubber or more rigid plastics such as PVC.

Although polyurethanes are more expensive than PVC or rubber, this new grade meets higher performance standards and is more durable. For example, polyurethanes formulated with new polyester polyols can be used to make print rollers (such as those used in newspaper printing) that last longer than those made of rubber and PVC. "The polyurethanes business is one of the faster growing businesses we deal with, posting volume growth rates of roughly 10%," adds Hopper.

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	Antioxidant	Antistat	Blowing agent	Catalyst, peroxide	Catalyst, polyurethane	Flame retardant	Heat stabilizer	Impact modifier	UV stabilizer	Lubricant	Processing aid
ABS		●	●			●	●	●		●	●
Acrylic		●	●	●		●				●	
Epoxy		●		●		●	●	●		●	
HDPE		●	●	●		●		●		●	●
LDPE		●	●	●		●		●		●	●
Nylon		●	●			●				●	
Polycarbonate		●	●			●		●			
Polyester, thermoplastic		●	●	●		●		●			
Polyester, unsaturated		●	●	●		●		●		●	
Phenolic				●		●				●	
Polypropylene		●	●	●		●		●		●	●
Polystyrene		●	●	●		●		●		●	
Polyurethane		●				●	●	●		●	
PVC		●	●	●		●	●	●		●	●

Source: SRI International estimates

Expanding into new applications is something that Ciba-Geigy is also trying to do with its hindered-amine light stabilizers (HALS). In 1990, HALS accounted for 38% of the total volume of light stabilizers sold in the U.S.; the other major types of light stabilizers include benzophenone and benzotriazole, according to a study done on light stabilizers in April of this year by Phillip Townsend Associates. HALS, which were developed many years ago by Ciba-Geigy, are efficient at low concentrations and can be used in a broad range of polymers, especially polypropylene and low-density polyethylene. The continued growth of HALS will depend not only on application growths but also on the fact that they are being used to replace benzophenones. Ciba-Geigy has been successful in replacing benzophenones with HALS in most resins. However, cost and performance considerations likely will continue to drive benzophenone use in PVC, notes the Phillip Townsend Associates report. That's because resins containing halogens or sulfur are extremely incompatible for use with HALS.

Developing alternative products designed to meet anticipated or existing legislation is one route to business expansion that many additives producers are taking. Environmental pressures facing additive producers represent an opportunity for growth, says Butch Hite, business manager for the polymer additives and specialty monomers business unit at Eastman Chemical.

Clearly, this kind of opportunity exists in the heat-stabilizers market. Driven by legislative action and concerns by users about health risks associated with several commonly used products, consumption patterns of heat stabilizers used in plastics likely will change significantly during the next five years, according to a Phillip Townsend Associates' study. The payoff could be sig-

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nificant for additive producers that are poised to meet those changing needs.

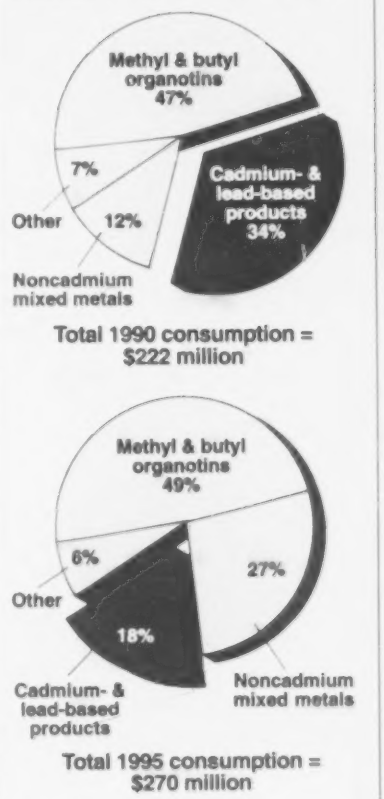
According to this study, more than $200 million worth of heat stabilizers were consumed by the U.S. plastics industry in 1990. "However, a more important point to consider," says Joel Kopinsky, research analyst with Phillip Townsend Associates, "is that lead- and cadmium-containing stabilizers, which are under increasing scrutiny for health and safety reasons, accounted for more than $75 million of the business."

The overall heat-stabilizer business is expected to grow at a healthy rate of 4% annually through 1995, net of any price increases, notes the Phillip Townsend Associates study. However, because cadmium and lead stabilizers likely will be replaced with competitive products, certain subsegments of the market will grow at more than 40% per year during the same period. "These developments will create problems for some suppliers but opportunities for others," reports Peter Gavrushenko, vice president of the consulting firm.

The pressure for reducing the use of cadmium- and lead-containing products is coming from many sources, including legislation proposed by state and federal agencies. For example, the Occupational Safety & Health Administration has issued a Notice of Proposed Rulemaking that will significantly reduce the permissible exposure limit for cadmium. In addition, a new risk assessment study on lead toxicity is expected within the next few years.

Connecticut, Iowa, Maine, New Hampshire, and Wisconsin have already passed heavy-metal reduction laws, and similar legislation is imminent in Pennsylvania and New Jersey. Sen. Harry Reid (D.-Nev.) has introduced a bill requiring the Environmental Protection Agency to ban or limit the use of lead in products for which substitutes are available. In addition, EPA has proposed revising standards for drinking water to reduce allowable cadmium from 10 to 5 µg per L. Cadmium and cadmium compounds are on California's Proposition-65 toxic chemical list that prohibits any discharge of cadmium into drinking sources. Outside the U.S., the European Community (EC) has followed the lead of Denmark, the Netherlands, Sweden, and Switzerland by proposing a ban on cadmium-containing stabilizers.

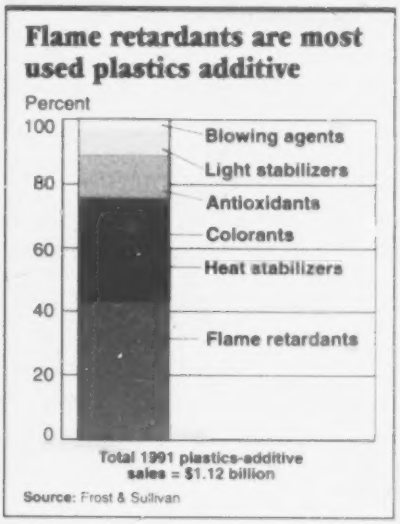
Cadmium-, lead-based heat stabilizer use will shrink



Note: Percentage of dollars.
Source: Phillip Townsend Associates

Anticipating the passage of more legislation, Witco's Argus Division is moving to phase out its cadmium-containing and lead-containing stabilizers "as soon as possible. Realistically, we hope to have 50% replacement of those products by the end of this year, but it depends almost completely on our customers' demands," says Victor R. Struber, Argus' director of marketing. "We can't move any faster than they are willing to evaluate these new materials."

At the same time, Argus has taken an aggressive approach toward developing and marketing alternative stabilizers. The division has introduced its Mark 4700 line of liquid noncadmium heat stabilizers, which are used in nonflexible PVC, and its Mark 6700 series of materials to replace its solid cadmium stabilizers, some of which go into PVC for electrical insulation end uses. "We are doing no new development work with anything but the noncadmi-



ums in the mixed-metal area," says Struber. Mixed-metal stabilizers, which include both cadmium and noncadmium stabilizers, primarily go into flexible PVC or plasticized PVC used for shower curtains or wall coverings, for example.

In addition to its move away from cadmium stabilizers, Argus just completed a 50% capacity expansion for methyl organotin stabilizers at its Taft, La., facility. The major application for these products is in processing rigid PVC used in construction for siding, door and window frames, and pipe.

In addition, last October, Witco formed a cooperative technical and marketing agreement with Ciba-Geigy Marienberg, the wholly owned German subsidiary of Ciba-Geigy Ltd. in Basel, Switzerland. Under the agreement, the Argus Division and Ciba-Geigy Marienberg will share technical information and cooperate in the development of mixed-metal stabilizers for the PVC market. "We are excited by the opportunities afforded us with this agreement," adds Nirmal Jain, a Witco vice president and general manager of the Argus Division. "Witco has been on the leading edge of the development of mixed-metal stabilizers, and we believe the additional resources now available to us will increase our technical and marketing strengths. We are especially interested in pooling our technology with Ciba-Geigy in noncadmium PVC stabilizers."

Concurrently, Witco entered into a marketing agreement, which excludes North America and Japan, with Ciba-Geigy Marienberg for methyltin stabilizers produced by Argus. "This venture increases our market penetration worldwide," says William E. Mahoney, Witco vice president, "while providing technology to sustain growth in the years ahead."

While Ciba-Geigy cooperates with Witco in the development of alternative stabilizers, it has its eye on some other regulatory issues as well. The company's U.S. pigments division has been developing pigments free of heavy metals to be in compliance with the Coalition of Northeast Governors (CONEG) in advance of the deadlines that were set by the coalition. CONEG has mandated that in all packaging, trace levels of four heavy metals—lead, hexavalent chromium, mercury, and cadmium—must be limited. It has proposed limits on the presence of these metals to 600 ppm one year after enactment of the legislation, 250 ppm two years after the enactment, and 100 ppm four years after the enactment. Thirteen states have passed laws limiting the levels of these four heavy metals and 13 more have introduced similar laws.

In response to this growing legislative effort, the pigments industry has sought to develop environmentally friendly pigments for bright, stable colors free of the four CONEG heavy metals and other potentially toxic or carcinogenic substances, says Eva M. Vary, director of product safety for Ciba-Geigy's U.S. pigments division. Developing pigments that are free of heavy metals but that have the same high opacity, heat stability, light fastness, and low cost of heavy-metal-containing pigments has been a challenge for researchers.

Ciba-Geigy says it has met this challenge. Nine of every 10 products in the company's U.S. pigments line are free of heavy metals; the others contain complex metals in insoluble form. This is important to Ciba-Geigy's pigment customers, says Vary, "because most packagers are currently requiring them to obtain certification that trace levels of the four heavy metals are below 100 ppm, exceeding current CONEG laws."

CONEG targeted the packaging industry when it discovered that containers and packaging constituted more than 30% of the solid waste generated in this country, raising fears that heavy metals in these products were entering

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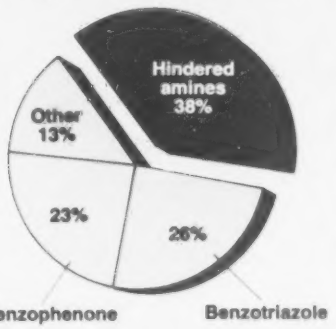
Hindered amines take 38% of light-stabilizer market



Total 1990 sales = $162 million

Note: Percents are by volume.
Source: Phillip Townsend Associates

the groundwater through landfills containing incinerator-ash residues and entering the atmosphere during incineration. Indeed, the plastics industry has also been affected outside the packaging area because heavy-metal pigments have been widely used in many plastics applications.

Helping pigment users make the transition to alternative pigments and sometimes alternative technologies requires more comprehensive support at all levels than ever before, says Vary. "We have to work closely with our customers to help them integrate the new products into their existing processes economically."

The possibility of regulatory phaseout is also looming large over another additive class—halogenated flame retardants. The jury is still out on whether that phaseout will come to pass. Some companies are busy developing and touting alternative products, whereas producers of halogenated flame retardants continue to defend the safety and efficacy of their products.

Some additive producers, such as Alusuisse-Lonza's Martinswerk Group, Bergheim, Germany, say traditional flame retardants based on halogen and phosphorous compounds cause the formation of toxic and corrosive decomposition products during their flame-retardant reaction, thus causing significant secondary damage. The company says recent investigations in Germany and the U.K. showed that more than two thirds of the fire deaths that occur every year are caused by inhalation of smoke and toxic gases and not by contact with fire. On the basis of these findings, Roman Nykyforuk, Lonza's director of marketing in its inorganics group, speculates that regulations limiting or possibly banning the use of brominated flame retardants could develop in Europe, and like so many other regulations have done, migrate to the U.S. legislative system.

"But that possibility is remote," says John McChesney, a marketing communications manager for Ethyl. In a position paper on brominated flame-retardant regulatory and safety issues, Ethyl, a producer of these products, points out that no regulation is in effect anywhere around the world banning the use of brominated flame retardants, although regulations have been proposed. In Europe, a regulation was proposed that would limit the use of brominated diphenyl oxides in several European countries, but this regulation has been blocked by the EC. One reason for the block, Ethyl points out, is that the U.K. is concerned that the proposed directive would increase the hazard from accidental fires since adequate substitutes do not exist for all uses of the diphenyl oxides. Outside the EC, a few individual European countries have proposed legislation dealing with these products, but nothing has yet been passed.

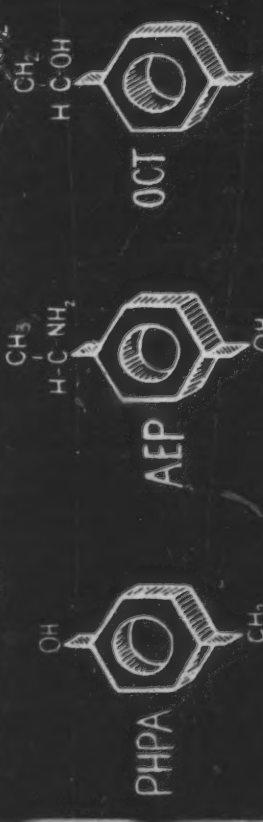
In the U.S., EPA has proposed testing several flame retardants, in-

U.S. plastics additives demand will grow roughly 4% annually through 1996

Millions of lb	1990	1991	1996	2000	% annual growth rate 1990–91	1991–96
Fillers	3615	5,750	7,180	8,225	4.3%	4.5%
Plasticizers	1325	1,770	2,000	2,190	2.7	2.5
Reinforcements	575	925	1,100	1,250	4.4	3.5
Flame retardants	393	690	905	1,040	5.3	5.6
Colorants	283	507	610	695	5.4	3.8
Impact modifiers	70	140	170	195	6.5	4.0
Other	283	448	535	605	4.3	3.6
TOTAL	6544	10,230	12,500	14,200	4.1%	4.1%

Source: Freedonia Group

Developmental Intermediates



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cluding decabromodiphenyl oxide (DBDPO), for health and environmental effects, but Ethyl anticipates that no decision on the final contents of the rule will be reached before early 1993. EPA also required testing DBDPO, along with a number of other brominated and chlorinated products, for dioxin and furan content. However, it discovered that no analytical method was available to meet EPA's limit of quantification and isomer specificity requirements, so an extensive, three-year methods development program was undertaken to meet these requirements. The analytical difficulties have recently been solved and results are anticipated sometime in 1992.

Ethyl says it is confident its products will come up clean. "Analytical results to date indicate DBDPO should not [cause] brominated dioxin-furan contamination," the company adds. Many toxicological studies have been conducted on DBDPO and show it has a "wide margin of safety. The many toxicological studies available on DBDPO are one of its advantages—much is known about its toxicology and the product has many years of safe industrial use," the company notes.

Ethyl continues to bank on growth for brominated flame retardants. The firm is "currently adding what will amount to $50 million worth of new capacity for several of our brominated flame retardants" at the Magnolia, Ark., facility, says McChesney. Within that project, Ethyl is quadrupling capacity for its proprietary Saytex BT93W product used primarily in styrenics. Despite concerns about the products, Ethyl anticipates demand for brominated flame retardants will be spurred partly by growth in demand for high-impact polystyrene, which is being used increasingly as a cost-effective replacement for acrylonitrile-butadiene-styrene, says McChesney.

For its part, Lonza maintains that the threat of halogenated flame-retardant legislation alone has boosted demand for flame retardants such as aluminum trihydrate (ATH) and magnesium hydroxide, which are halogen-free, nontoxic, and noncorrosive. The flame-retardant reaction for these products is based on endothermic decomposition of the hydroxides to the corresponding oxides and water, thus no toxic or corrosive gases are formed in the case of fire, says the company.

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MONDAY, OCTOBER 26

RICHARD J.V. JOHNSON, President, Welcoming of Guests
WILLIAM N. LIPSCOMB, Introductory Remarks

SESSION I
WILLIAM N. LIPSCOMB, Presiding Chair

SPECIES ADAPTION OF THE ALLOSTERIC REGULATION OF HAEMOGLOBIN
MAX F. PERUTZ

ACTIVITY AND ALLOSTERIC REGULATION IN GLYCOGEN PHOSPHORYLASE
LOUISE N. JOHNSON

SESSION II
MAX F. PERUTZ, Presiding Chair

ACTIVITY AND ALLOSTERIC REGULATION IN BACTERIAL PHOSPHOFRUCTOKINASE
PHILIP R. EVANS

ACTIVITY AND ALLOSTERIC REGULATION IN FRUCTOSE 1,6-BISPHOSPHATASE
JIN-YUN LIANG

TUESDAY, OCTOBER 27

SESSION III
ROBERT HUBER, Presiding Chair

ACTIVITY AND ALLOSTERIC REGULATION IN ASPARTATE TRANSCARBAMYLASE
WILLIAM N. LIPSCOMB

ALLOSTERIC EFFECTS IN THE ASPARTATE RECEPTOR
DANIEL E. KOSHLAND, JR.

LUNCHEON, 1992 WELCH AWARDEE

CLUSTERS, CHEMISTRY AND NANOTECHNOLOGY
RICHARD E. SMALLEY

SESSION IV
DANIEL E. KOSHLAND, JR., Presiding Chair

ALLOSTERIC EFFECTS IN RecA PROTEIN
THOMAS A. STEITZ

ALLOSTERIC EFFECTS IN PROTEIN SUBUNITS AND AT PROTEIN MEMBRANE INTERFACES
ROBERT HUBER

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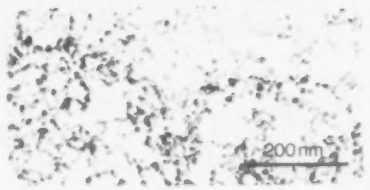
CIRCLE 35 ON READER SERVICE CARD

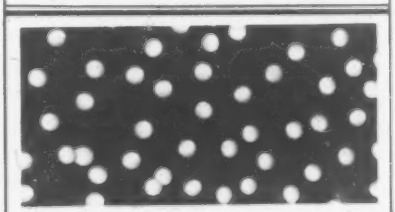
New Silica Sol is it !!



ST-UP chain molecules of silica. 5-20nm in width 40-300nm in length

ST-O negatively charged small particle sol (ca. 12nm), not including anion and cation without stabilizing ion

for Binder? Micro Filler? or?



Colloidal Silica dispersed in organic solvent.

Type	SiO%	Dispersant
IPA-ST	30	Isopropanol
EG-ST	20	Ethyleneglycol
DMAC-ST	20	Dimethylacetoamide
NPC-ST	20	Ethyleneglycol-mono-n-propylether

Particle Diameter 10-20nm.
Available product is much more.

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CIRCLE 22 ON READER SERVICE CARD

Technician at Ciba-Geigy measures the melt flow index of an extruded polymer

Aiming to take advantage of the trend toward using these alternative products, in May Alusuisse-Lonza dedicated a new facility in Austria, a joint venture with Veitscher Magnesit, for the manufacture of its new magnesium hydroxide product called Magnifin. The magnesium hydroxide product "complements our Martinal ATH product line because it has a higher thermal stability so that it can be applied in polymer systems up to 340 °C," says Nykyforuk. This will allow the company to expand into other markets such as polypropylene and nylon. Its Martinal ATH is only suitable for use as a flame retardant in PVC and polyethylene, which are processed at lower temperatures.

Although regulations are presenting opportunities, additive producers are quick to point out that the proliferation of industry rules is also having a negative effect on their business. The spiraling number of regulations affecting the additives business "is a problem we all face as producers. And I don't deny the need for it," says Hüls' Magram. "The basis for the regulations being promulgated is correct, but regulators need to be driven less by emotion and more by science."

More regulation means that companies are being forced to spend more capital and human resources on compliance. "Five years ago we had one person in regulatory affairs, now we have three. It's a huge overhead expense," says Hall's Hopper.

Regulators are becoming overly stringent in their inspection processes, say many additive suppliers. For example, at one time the aromatics content of plant effluents was considered to be too high "if you could smell it," but now regulators are testing for those chemicals at the parts-per-billion level. "It's clearly much more difficult to run a plant now than it used to be," says Hopper. The bottom line is that "it's getting more difficult to meet market needs as more and more materials are being monitored at ever lower levels," he adds.

In the course of upgrading their plants, companies are also improving their facilities' environmental profiles. Within the next couple of weeks, American Cyanamid will announce expansion and modernization of its plant in Willow Island, W.Va. The project centers around light-stabilizer and antioxidant production, but will also involve work to reduce emissions substantially, according to American Cyanamid's Avrin.

In addition to affecting how additives producers' plants are run, an increasing number of regulations are also affecting the rate at which new products are introduced. The greatest pressure additives producers now face is the rising cost of new product development and new product introduction, says Avrin. "At Cyanamid, we have a range of products that offer unique performance advantages in niche markets, but with the continued rising costs of environmental compliance and product registration, it is becoming more difficult to expect that new specialty products can absorb all these costs and still be competitive in the marketplace against well-established products that might not even be as effective."

Hopper predicts many companies in the business today will not be in business five years from now because of "regulatory shutdown." "The smaller companies can't cope. These regulations may allow only the large to survive."

Recycling may increase demand for additives

One of the biggest issues affecting the plastics business now is that of recycling. The industry is facing increasing pressure from the public and environmental groups to step up its role, but numerous technical and logistical problems stand in the way of widespread recycling.

Recognizing this, plastics additives producers say they have been looking for ways to help plastic recyclers solve these problems and thereby open up new niches for their expertise and products. But for the most part, additive producers report that their involvement in furthering the recycling effort is premature.

"Right now the problem for recycling is more physical—how to collect and segregate," says Allan Kushins, director of marketing for the functional chemicals group of Lonza, Fair Lawn, N.J. "Where there is a challenge [that calls for use of additives], the additives are not any different than the ones used for virgin resin. We'd really like to be part of [recycling efforts], but we don't see a role for the additives business right now," he adds. "It's not the additive producers that are going to be the driving force, its the resin producers. We'll work very closely with them, but they'll need to tell us their requirements."

Another limiting factor for additive producers: The recycling effort is just getting off the ground for plastics, such as polyvinyl chloride, that rely heavily on additives, notes John Dellevigne, executive vice president of Hüls' plastics division. The most commonly recycled plastics, polyethylene terephthlate and high-density polyethylene (HDPE), need relatively few additives.

Still, it's hard for additive producers to ignore the market considering that, by the year 2000, 6% of the total U.S. polyolefin market will be recycled, says Larry D. Rosenberg, a consultant with ChemSystems, Tarrytown, N.Y. Even from a small base of additives consumption, the market for additives used in recycling HDPE, polypropylene, low-density polyethylene, and linear low-density polyethylene will be sizable, he adds. "Recycled polyolefins are susceptible to degradation during compounding and melt reprocessing. This requires, in some cases, adding more antioxidants to prevent viscosity changes and discoloration. The trend is to err on the side of additional antioxidants during recycling."

The good news for additive producers is that as the recycling effort becomes more mature, they may be able to play a bigger role. Recognizing that, producers say they want to be ready to meet that demand. "It is definitely something we are working on, although we don't yet have any specific new products and nothing is commercial yet," says Avron Magram, vice president and general manager for the plastics additives and specialty lubricants group at Hüls America. "It is an exciting new business that could eventually open up opportunities for new additives."

One challenge to additive producers, Magram says, is developing products that disperse and mix in well with recycled material. Mixing additives into granular recycled plastic is more difficult than mixing them into a virgin plastic in a powder form, he notes.

Another opportunity for additives producers is developing antioxidants or plasticizers that not only "do the original job in the virgin resin" but also remain in the resin and continue to work as it is recycled, eliminating the need to add more. But selling that "add-on" processibility benefit to resin producers may prove to be difficult, says William Avrin, vice president and general manager for polymer additives at American Cyanamid. The resin manufacturers must pay an additional first application cost for this benefit even though they may not be handling

Indeed, the extremely fragmented plastics additives market is expected to become somewhat more concentrated as companies shut down or are bought out by larger producers. As in many fragmented industries, much of the plastics additives business is already concentrated in the hands of a few large companies. In 1991, the five leading firms—Ciba-Geigy, Akzo Chemical, Ethyl, Great Lakes Chemical, and Witco Chemical—accounted for 36% of the total market for plastics additives, according to a report on the U.S. market for plastics additives by consulting firm Frost & Sullivan, New York City.

The number of plastics producers is shrinking as well. As the larger U.S. resin producers acquire companies, a greater proportion of them are based outside the U.S. And while resin producers expand their geographic focus, additive producers say they must also globalize their business in order to compete. "It's hard to sell to a company like H. B. Fuller, 3M, or Du Pont if you cannot distribute your products and provide customer service outside the U.S.," says Hopper. "Every additive producer that wants to compete today must have a distribution channel that's global."

End-user companies and automobile companies in particular are becoming more global and are looking for "single sources" able to supply across broader geographic boundaries, notes Allan Kushins, director of marketing for Lonza's functional chemicals group. "For example, if a European automobile company comes into the U.S., they are looking for the same supplier that sells them the product in Europe. And the same holds true for U.S. end users. So our product goes from here to Europe for the same reason."

Another driving force behind the globalization of the plastics and additives businesses is the opening up of trade boundaries. "I think remarkable things will happen if the new trade agreements [with] Mexico and Canada are finalized," says Hopper. For example, "Much of what's now made in Southeast Asia, such as urethane-based shoes and apparel accessories, will be made in Mexico within the next five years," he predicts.

In anticipation of trade barriers coming down in Europe and North America, Witco has been making a concerted effort to become more global and to take advantage of the resultant opportunities, says Struber. Just last month, for example, Witco signed a definitive agreement to purchase the industrial chemicals and natural substances divisions from Germany's Schering A.G. The businesses will augment Witco's plastics additives business as well as others. William R. Toller, chairman of the board and chief executive of Witco says, "This acquisition represents a significant move toward making Witco a

the resin when it is recycled. "It's too early to tell whether we will be able to market these [recyclability] advantages."

When more recyclers start to recycle a heterogeneous stream of postconsumer plastics into finished products such as park benches, "then plastics additives will become interesting and necessary" says Hüls' Dellevigne. A recent study by Houston-based Phillip Townsend Associates, says, "The greatest area of potential for compatibilizers is in recycling of plastics." In fact, by 1995 Phillip Townsend Associates forecasts that recycling will account for more than half the demand for compatibilizers.

Although few, if any, additives producers have yet to develop or market anything novel to recyclers, many companies are responding to their customers' environmental concerns in another way—offering their products in recyclable or returnable packaging. "There's been a lot of interest and activity in this area during the past six to 12 months," notes John McChesney, a marketing communications manager for Ethyl, which is providing some of its additives in these types of packaging.

"Nobody wants to send product packages into landfills," says Janet Crawford, business manager for additives in Akzo's polymer production chemicals group based in Chicago. "Our customers are aware of that and we're obviously aware of that. It fits in with the product stewardship, cradle-to-grave aspect of the Chemical Manufacturers Association's Responsible Care initiative. We want to take care of our products and packaging the whole way through." Akzo is considering shipping more of its additive products in packages such as supersacks, which reduce packaging, or in returnable totebins and liquibins. It is also looking into use of recyclable fiber drums.

Likewise, at its new granulation, blending, and packaging unit at its McIntosh, Ala., production site, Ciba-Geigy has built in advanced capabilities for providing customers with environmentally preferred packaging options, says Paul Simonetti, a marketing communications manager for the company's additives and pigments division. For example, some of the company's antioxidants are available in 1200-lb bulk containers, or recyclable 44-lb polyethylene bags, all designed to reduce or eliminate packaging waste.

In addition, Ciba-Geigy now packages antioxidants for polystyrene production in a totally consumable bag. The result of a collaborative development effort among Ciba-Geigy; Bonar Inc., Burlington, Ontario; and A.V.P. Extrusions Ltd., Newcastle, Ontario, the package is a rubber-modified polystyrene package that can be added into the polystyrene production process along with the antioxidant without any effect on the process. Using the polystyrene bag requires no additional equipment or expense for the manufacturer, says Simonetti. A special Food & Drug Administration-approved ink is used on the package—it does not affect chemical reactions occurring during polystyrene production, says the company. The new package avoids the environmental problem of disposing of bulky packaging such as fiber drums. At the same time, it provides a convenient way to incorporate Ciba-Geigy's Irganox 1076 FF granular antioxidant into the process.

The consumable bags are not the best solution for all resin producers. "Some of our customers don't want to throw the polyethylene bags we use into the process because they like to have stringent control over the final quality of their product," says Crawford. "They want to know the history and source of everything that goes into their final product including what the bag is made of and who made it."

global chemical company by doubling our international revenues." Witco's technical and marketing agreement with Ciba-Geigy Marienberg in the stabilizer area is another move aimed at increasing its market penetration worldwide, Struber points out.

Ethyl is another of the many additives suppliers that says it is broadening its participation in markets outside the U.S. For its part, the company is slated to complete a new technical center at Leouvain-la-Neuve, Belgium, by early 1993. Eastman Chemical Co., too, is expanding its sales and technical service efforts to support worldwide growth, says Hite.

Meanwhile, other companies are reshuffling their internal divisions in an attempt to gain more clout on a global basis. For example, in an effort to promote Lonza's corporate identity as a global supplier of additives and processing aids to the plastics industry, late last year the company formed a plastics marketing team. The new team, which is made up of representatives from the company's functional and inorganic chemicals groups, will emphasize the worldwide commitment to the plastics industry by the Alusuisse-Lonza Group of companies, of which Lonza is a part. The new group aims to unify and market internal and external lubricants, antistats, antifogs, flame-retardant additives, compatibilizers, graphite, carbon additives, and more, in one focused effort.

As the plastics additives business becomes increasingly global, producers must work even harder to keep up with technology on a worldwide basis. "There's no question that the additives business is becoming more global, in a technical sense," says John Dellevigne, executive vice president of Hüls' plastics division. "It used to be that developed countries had locks on certain types of process and formulation technology. But now you have companies in places like India or Malaysia that are up to speed on the latest available plastics technology. As a result, it's tough for a company to keep an edge with an advantageous formulation or product. The world finds out about it and develops an alternative that's just as good. So today, products are becoming more similar around the world. Advantages in the plastics business are short-lived."

Still, there are many new problems to be solved with new technology and that fact is what makes many producers "bullish" on the outlook for the plastics additives business. Says Magram of Hüls: "I am wildly enthusiastic about the potential for growth for plastics additives. All plastics have performance deficiencies and a key way to overcome them is to use additives. Those challenges continue to crop up faster than we can solve them and they all represent new opportunities for growth." □